

X-ray flares/bursts from GRS 1915+105 and the two component accretion flow

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ABSTRACT

We present results of our analysis of a set of RXTE/PCA observations of X-ray flares/bursts with burst cycle ranging from 30 to 1300 s from the Galactic X-ray transient source GRS 1915+105 during last four years. These flares/bursts can be classified into four types: 1) regular bursts with short burst phase of ~ 20 s (R1), 2) regular bursts with short quiescent phase of ~ 20 s (R2), 3) long regular bursts (R3) with burst cycle ≥ 1000 s, and 4) irregular bursts (IR). For all the observed bursts, the duration of the quiescent phase is inversely proportional to the square of the QPO frequency (2–10 Hz).

Introduction

The Galactic X-ray transient source GRS 1915+105 has shown spectacular X-ray variability during last four years of its observation by RXTE and other satellites (Greiner et al., 1996, Yadav et al., 1999, Belloni et al., 2000). This source was discovered in 1992 with the WATCH all sky X-ray monitor onboard the GRANAT satellite (Castro-Tirado et al. 1994). The X-ray intensity was found to vary on a variety of time scales and the light curve showed a complicated pattern of dips and rapid transitions between high and low intensity (Belloni et al., 1997, Taam et al., 1997). Recently, Yadav et al. (1999) have made a detailed study of various types of X-ray bursts seen in GRS 1915+105 from IXAE/PPCs observations during 1997 June - August and attempted to explain these bursts in the light of the recent theories of advective accretion disks. In X-ray astronomy, the terminology X-ray burst is used for type I and type II classical bursts seen in LMXBs. The timing and spectral properties of the flares/bursts described here are completely different than that of the classical bursts (Yadav & Rao, 2000).

In Table 1, we list details of RXTE/PCA observations discussed here along with some of the properties of the observed X-ray flares/bursts. Each burst cycle consists of a low flux quiescent phase followed by a high flux burst phase and the fast transition in less than 10 s. The dips or the quiescent phase in these observations are spectrally hard while the brighter portions (the burst phase) are soft (Yadav, 2001). For details of these observations as well as of our analysis please see Yadav & Rao (2000).

Table I.
Summary of selected observations of GRS 1915+105

Date (UT)	Exposure (s)	Type of Bursts	ASM ^a Flux	Rec. Time (s)	Av. Q. Flux
1996 April 06 05:40	5600	Regular (R2)	99.4	280 ^b	6200
1996 Oct 07 05:44	7000	Regular (R3)	98.8	1150 ^b	3200
1997 May 26 12:25	3215	Regular (R1b)	47.6	105 ^b	7500
1997 June 18 14:17	3472	Irregular (IR)	61.5	var.	var.
1997 June 22 19:27	2550	Regular (R1a)	59.7	55 ^b	8700

Q. Flux= average quiescent time flux (c/s), var. = variable, ^aMean ASM flux (c/s) for a day, ^bMean burst recurrence time.

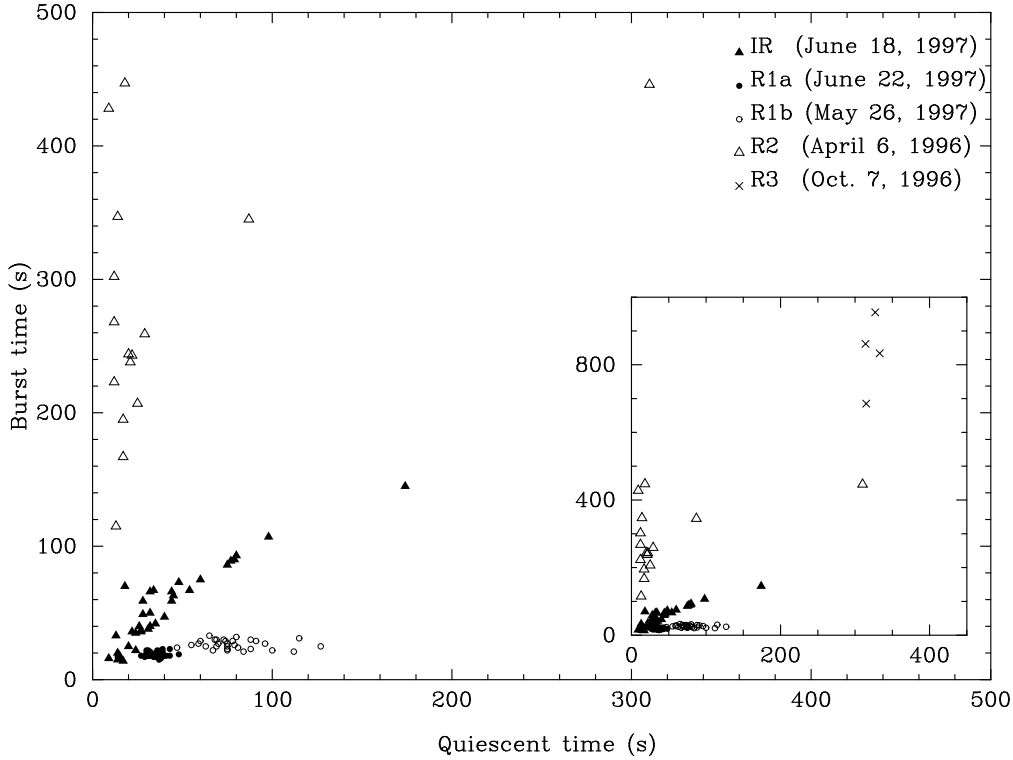


Fig. 1. Plot of the quiescent time and the burst duration for all the bursts.

Results and discussion

On the basis of timing properties, these flares/bursts can broadly be put into two classes: regular bursts centered around a fixed period with low dispersion ($\delta P/P \sim 1 - 50\%$) and irregular bursts with no fixed periodicity ($\delta P/P > 50\%$). These flares/bursts can be classified into four types: 1) regular bursts with short burst phase of ~ 20 s (R1) with $\delta P/P \sim 1-10\%$, 2) regular bursts with short quiescent phase of ~ 20 s (R2) with $\delta P/P$ up to 50% , 3) long regular bursts (R3) with burst cycle ≥ 1000 s and $\delta P/P \sim 1-15\%$, and 4) irregular bursts (IR) (see figure 1). We have measured the quiescent time and the burst duration for all types of bursts and results are shown in Figure 1. The data of IR bursts seen on 1997 June 18 fall diagonally; clearly showing a strong correlation between the burst duration and the quiescent time. On the other hand, data for different types of regular bursts fall on either horizontal or vertical branches implying no such correlation for the regular bursts (Yadav et al., 1999). The R1a and R1b regular bursts fall on the horizontal branch with the burst time ~ 20 s. The R2 regular bursts fall on the vertical branch with the quiescent time ~ 20 s while the R3 regular bursts fall on vertical branch with the quiescent time ~ 320 s (this is shown in the inset of Figure 1).

The most striking features of these flares/bursts are slow exponential rise, sharp linear decay and hardening of spectrum as burst progresses (Paul et al. 1998). The decay time scales are shorter than the rise time scales. In sharp contrast, the decay time is longer than the rise time in classical bursts and spectrum is initially hard and becomes softer as the burst decays (Lewin et al., 1995). Yadav et al. (1999) have suggested that the source is in a high-soft state during the burst phase and in a low-hard state during the quiescent phase on the basis of available spectral observations and derived disk parameters of GRS 1915+105. The fast time scale for the transition of the state is explained by invoking the appearance and disappearance of the advective disk in its viscous time scale. Such fast changes of states are possible in the Two Component Accretion Flows (TCAF) where the advective disk covers the standard thin disk (Chakrabarti, 1996, Chakrabarti and Titarchuk, 1995). Chakrabarti & Manickam (2000) have provided a relation; $t_{off} = f(\Theta_{\dot{M}})\nu_I^{-2}$ based on TCAF. Where t_{off} is the duration of off state (duration in which the sonic sphere becomes ready for catastrophic Compton cooling), ν_I is the intermediate QPO frequency between $2 - 10$ Hz, and $\Theta_{\dot{M}}$ is a dimensionless parameter defined as $\Theta_{\dot{M}} = (\Theta_{out}/\Theta_{in}) \times \dot{m}_d$ where Θ_{in} and Θ_{out} are the solid angles of the

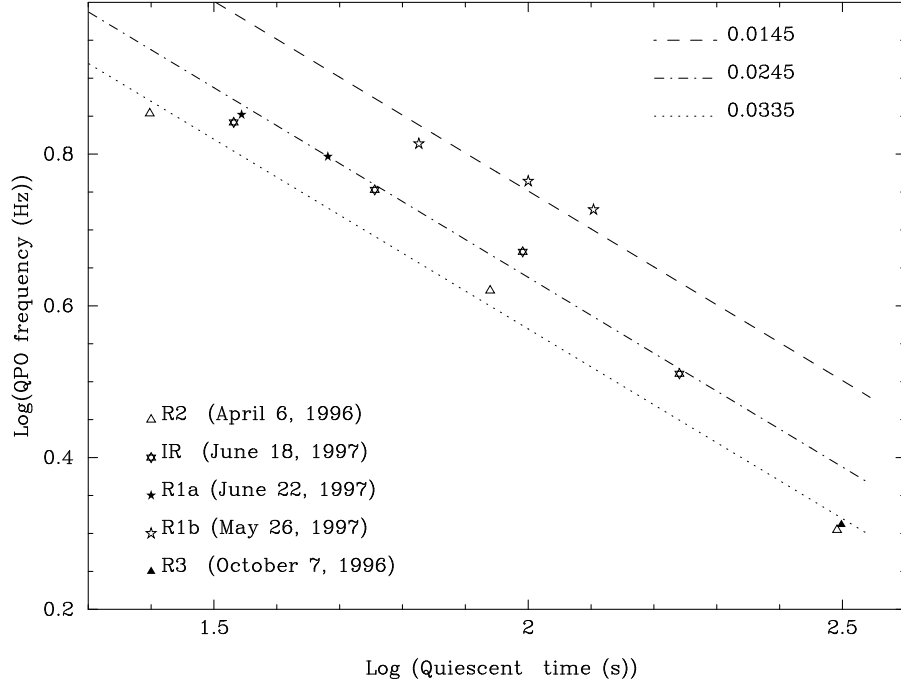


Fig. 2. Variation of QPO frequency ν_I (minimum) with the quiescent time for different types of X-ray flares/bursts (data points). Plotted lines are the quiescent time $\propto \nu_I^{-2}$ for different values of $\Theta_{\dot{M}}$.

inflow & outflow respectively and \dot{m}_d is the disk accretion rate in units of Eddington accretion rate.

In Figure 2, we plot the above relation in the log - log scale taking t_{off} as the quiescent time for $\Theta_{\dot{M}} = 0.0145, 0.0245$ and 0.0335 alongwith our QPO results (points). These results are in good agreement. The data points of R2 and R3 bursts when ASM flux was 99.4 & 98.8 c/s respectively fall along the dotted line with $\Theta_{\dot{M}} = 0.0335$ (see table 1). The data points of R1a and IR bursts when ASM flux was 59.7 and 61.5 c/s respectively fall along the dashed - dotted line ($\Theta_{\dot{M}} = 0.0245$). The data points of R1b bursts during which ASM flux has lowest value of 47.6 c/s fall along the dashed line ($\Theta_{\dot{M}} = 0.0145$). It may be noted here that the $\Theta_{\dot{M}}$ and the ASM flux though determined independently agree well for different types of flares/bursts as both of these are related to the disk accretion rate \dot{m}_d . Our results in Figure 2 suggest that the t_{off} represents the quiescent time of the flares/bursts which may or may not be of the order of the viscous time scales of the thin accretion disk.

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